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The impacts of agricultural development and trade on CO_2 emissions? Evidence from the Non-European Union countries

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ABSTRACT

The climate crisis and related events are often in the headline in recent years. The climate agreements reflected these concerns and called the researchers' attention to the urgent need for climate mitigation and adaptation policies. Many countries made new commitments during the latest United Nations Climate Conference (COP26) in November 2021 in Glasgow. In turn, scientists and experts worry that new pledges are not ambitious enough. The first environmental regulation was ratified in Great Britain in 1863. Later, the industrial and agricultural revolution stimulated pollution and brought about the emergence of environmental issues. The first agreement aiming to mitigate environmental pollution and stabilize greenhouse gas concentrations in the atmosphere was the United Nations Framework Convention on Climate Change (UNFCCC), adopted at the Rio Earth Summit in 1992. Behind the European Union, the contribution of the biggest polluter countries to climate change is also significant. The objective of the paper is to investigate the explanatory factors of CO_2 emission, focusing on the contribution of economic growth, agriculture, and trade along with free trade and climate agreements on climate change in Non-European Union member states, including the biggest emitters in the past two decades. In addition, it investigates the role of specific free trade agreements in emission cuts. The results showed an increase in CO_2 emissions in third countries, the reduction in the impact of agricultural export on greenhouse gas emissions, underlining the potential hidden effect of trade-related emissions between 2000 and 2018. NAFTA was encouraged while EFTA, ASEAN and MERCOSUR reduced emission growth. The USA, China, and Russia have the highest responsibility in controlling climate change. The findings reflect the limited progress and implementation of climate and trade policies and agricultural-related emissions in Non-EU countries.

1. Introduction

The consequences of global warming and climate change have frequently appeared in the headlines. The timeline of efforts made to reduce greenhouse gas emissions and impacts of climate change dates back a long time. The first environmental law was ratified in Great Britain in 1863 (Alkali Act, 1863). Later, the Industrial Revolution followed by the Agricultural Revolution brought about major changes in the economy, environment, and society. Some of these changes had positive effects, but environmental pollution increased.

The first agreement aiming to mitigate environmental pollution and to stabilize greenhouse gas concentrations in the atmosphere was the United Nations Framework Convention on Climate Change (UNFCCC), adopted at the Rio Earth Summit in 1992. In 1997, the Kyoto Protocol introduced legally binding emission reduction targets for developed countries. The success of the Kyoto Protocol and the Doha Amendment (the first and second commitment period of the Kyoto Protocol) was limited due to the exemption of developing countries from reduction requirements and the lack of an effective emissions trading scheme.

In 2015, a global climate agreement was signed in Paris, where country leaders have committed to limit global warming to below 2 degrees Celsius, compared to preindustrial levels. Many countries made new commitments during the latest United Nations Climate Conference COP26 (Conference of Parties) in November 2021. In turn, scientists and experts worried that the new pledges are not ambitious enough. Several countries have only resubmitted the same or less[1] emission target, while

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[1] Brazil and Mexico.

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some have not made new submissions at all (CAT, 2022a).

The insufficient achievements of the climate agreements, conferences reflected these concerns and called the researchers' and decision marker's attention to environmental issues, the urgent need for new national climate mitigation and adaptation policies. Greenhouse gases (GHGs) as the main engines of climate change are responsible for the greenhouse effect that leads to global warming. Human-driven GHG emissions can be divided into many activities stimulating GHG emissions, such as burning fossil fuels, electricity and heat production, industrial production, agriculture and land-use change (Wang et al., 2014; Zakarya et al., 2015; Krapivin et al., 2017). Among the other components, agriculture is responsible for 7–14% of global carbon dioxide emissions (Grace et al., 2014). In this context, Foley et al. (2011) emphasized that agriculture contributes 30–35% of global greenhouse gas emissions associated with methane emissions from livestock, emissions from the use of farm machinery, tropical deforestation, and emissions from fertilized soils. Moreover, the global food system is responsible for approximately 21–37 % of annual emissions using the indicator of the 100-year global warming potential (Mbow et al., 2019). According to Ritchie et al. (2020), Agriculture, Forestry, and Land Use (AFOLU) account directly for 18.4% of GHG emissions. Based on these statistics, on the whole, the food system (including refrigeration, food processing, packaging, and transport) accounts for one-quarter of greenhouse gas emissions.

Global agricultural trade has grown significantly during recent decades, and it experienced annual growth of 6 % from 2000 to 2016 (FAO, 2018). From world merchandise exports, agricultural products increased the most, growing by 3.1 % annually and 36% from 2008 to 2018 (WTO, 2019). In addition, agricultural trade has indirect environmental effects on climate change, for example, the expansion of export crops leading to deforestation and soil erosion, raising the issue of transportation-related energy use and emissions (Harris, 2004). In spite of its importance, the impact of the agricultural development and trade on GHG emissions, especially in Non-European Union countries is scarily investigated. The motivation of the study is to explore the trade-related determinants of agriculture and agro-food trade of CO_2, to adjust agricultural trade policy, focusing on countries that are not members of the European Union. The aim of the paper is to suggest recommendations for climate and trade policy makers of the biggest emitter countries to moderate economic growth, agriculture and trade-related GHG emissions. The objective of the research is to investigate the agricultural development and trade-specific explanatory factors of GHG emission including economic growth captured by the Environmental Kuznets Curve (EKC) hypothesis in the world economy, focusing on the contribution of third countries[2] (in this context, countries that are not joined to the European Union, called Non-EU countries), including the biggest emitters in the past two decades (2000–2018).

Behind the impacts of economic growth, agricultural development, and trade, the contribution of the research is to provide an empirical analysis of free trade agreements, and climate agreements on environmental pollution. More specifically, it also investigates the role of specific free trade agreements (EFTA, ASEAN, NAFTA and MERCOSUR) in climate mitigation.

2. Literature review

The anthropogenic GHG emissions are influenced by several economic sectors globally, such as energy, industry, buildings, transport and agriculture, forestry, and land use change. As Liu et al. (2019) stated in the analysis of 40 countries, fast economic growth is the primary driving force of global emission. In turn, a decline in emission intensity initiated by the improvement of energy efficiency and innovative technology can support emission reduction. Furthermore, the greater net export effects in developed countries indicate that developing countries may become pollution havens, accommodate dirty industries. Recent trends show stable emission levels in North America and modest drops in Europe, as fuel switches from coal to gas and in line with the boom of renewable energy sources (Lamb et al., 2021). In addition, China and India are the main contributors to GHG growth at global level (Liu et al., 2019). Environmental pollution is associated with economic development and growth.

2.1. Economic development and pollution

Regarding economic growth and climate change nexus, several researchers analysed the validity of the environmental Kuznets Curve (EKC) hypothesis. Balsalobre-Lorente et al. (2021a) researched the carbon dioxide neutralizing effect of energy innovation on international tourism in the EU-5 countries applying the EKC. Researchers confirmed the inverted U-shaped EKC hypothesis, as well as the Pollution Haven hypothesis (since higher FDI inflows increase the CO_2 emission). Furthermore, the results revealed that energy innovation moderates the effect of air transport on carbon dioxide emissions, while the promotion of renewable energy curbs emissions. In addition, (Balsalobre-Lorente et al., 2021a, 2021b, 2021c) evaluated the Low Carbon Development Hypothesis and the Environmental Kuznets Curve (EKC) framework using panel data in Portugal, Italy, Greece and Spain for the period 1995–2015. The econometric results validated the assumption of EKC. A direct connection between urban population and environmental degradation was revealed. Similarly to Balsalobre-Lorente, Leitão, (2021b) searched for the links between economic growth, corruption, renewable energy, international trade and carbon dioxide emissions using panel data for Portugal, Spain, Italy, Ireland, and Greece. The results suggest that corruption and economic growth have a stimulating impact on carbon dioxide emissions. In turn, the use of renewable energy and international trade can improve the quality of the environment. From this aspect, Leitão, (2021a) tested the relationship between trade intensity, energy consumption, income per capita, and carbon dioxide emissions in Portugal between 1970 and 2016. He revealed that trade intensity contributes to environmental improvements. Anser et al. (2021) explored the relationship between globalization, energy consumption, economic growth, and CO_2 emissions in South Asian countries employing the EKC framework from 1985 to 2019. They identified causality between GDP growth and carbon emissions, as well as bidirectional causality between economic growth and energy use. To continue, (Balsalobre-Lorente et al., 2021a, 2021b, 2021c) investigated the relationship between foreign direct investment, economic growth, urbanization, energy use and carbon emissions in BRICS countries between 1990 and 2014. The environmental Kuznets curve (EKC) and the pollution-haven hypothesis (PHH) were confirmed by the authors. The results show that urbanization contributes to the reduction of carbon emissions, while energy use is one of the main driving forces of the increase in carbon emissions. Moreover, Balsalobre-Lorente et al., 2022 extended the debate on environmental performance in PIIGS (Portugal, Italy, Ireland, Greece, and Spain) countries by examining the dynamic association between economic structure, foreign direct investment, renewable energy, urbanization, and carbon emissions from 1990 to 2019. They validated the environmental Kuznets curve and the Pollution-Heaven hypotheses. Among others, Doğan et al. (2022) analysed the effects of economic complexity on carbon emissions. They demonstrated that the environmental tax directly affects carbon emissions and lowers the effect of energy consumption and natural resources. Furthermore, the EKC hypothesis is validated in G7 countries. Last but not least, Jiang et al. (2022) applied an extended input-output, structural decomposition method, and energy utilization approach to examine the reduction in structural emissions of Chinese power and

[2] A country that is not a member of the European Union, a country or territory whose citizens do not enjoy the European Union's right to free movement.

heating industry from 2007 to 2015. The results show that from the investigation of structural aspects affecting CO_2 of the power and heating energy at the same time as the energy intensity, input, and energy composition played a critical role in minimizing CO_2 in Chinese energy sector with an increasing trend. Sinha et al. (2022) researched the constituents of inequality in access to energy and employed the Kaya-Theil decomposition method at the global level for 1990 and 2019. Scholars suggested that components of inequality in access to energy are rising and the vicious circle of energy poverty[3] might arise by the feedback loop. The work of Jahanger et al. (2022) explored the macroeconomic determinants of ecological footprint in developing countries (Asian, African, Latin American, and Caribbean regions) from 1990 to 2016. Results suggest that natural resources and financial development increase, while technological innovations reduce the ecological footprint. Finally, Usman and Balsalobre-Lorente (2022) examined the impact of industrialization, total reserves, and the expansion of financial, renewable, and natural resources on the ecological footprint using panel data for the period from 1990 to 2019 in the newly industrialized world. They illustrated that renewable energy and natural resources significantly reduce the emission level. On the contrary, industrialization, financial development, and total reserves increase pollution. The results confirmed that the conservation hypothesis exists between natural resources and ecological footprint. Behind the economic growth, agricultural activities play an active role through production, trade, and food consumption in GHG emissions and global warming.

2.2. *The pollution of agricultural activities*

Following energy (electricity, heat and transport, 73,2 %), agriculture, forestry, and land use (18.4 %) sectors are one of the most significant contributors to global GHG emissions (Ritchie and Roser, 2020). Baccini et al. (2012) suggested that tropical deforestation caused by agricultural purposes is one of the main sources of GHGs. Similar conclusions were drawn by Henders et al. (2015), indicating that the production of beef, soybeans, palm oil, and wood products is responsible for 40 % of total tropical deforestation. The article further states that the production of these goods results in notable carbon losses in Argentina, Bolivia, Brazil, Paraguay, Indonesia, Malaysia, and Papua New Guinea due to land-use change between 2000 and 2011.

Lamb et al. (2021) believe that the expansion of agriculture towards carbon-dense tropical forests is driven by recent increases in agriculture-related emissions in Latin America, South-East Asia, and Africa. In the Asian region, Maraseni et al. (2018) indicated that GHG emissions from rice cultivation have increased in China, India, Vietnam, Thailand, the Philippines, Myanmar, Bangladesh, and Indonesia between 1961 and 2014, while related emission intensities have gradually declined gradually due to increasing yields.

2.3. *Impact of trade on the environment*

Trade through the transport of goods may be associated with transboundary pollution and relocation of the manufacturing industries. However, it is economically advantageous for countries to pursue their trade advantage, increased pollution or natural resource degradation may also have accompanied by trade (Harris, 2004).

In particular, developed countries, where the service sector gained relative importance, can export emissions by relocating manufacturing activities to less developed regions of the world (Arrow et al., 1995; Stern et al., 1996). Moreover, pollution haven-countries attract manufacturing firms due to weak environmental regulations (Jaffe et al., 1995; Gallagher, 2004). Transnational trade and foreign direct investment can put downward pressure on countries' environmental standards and thus may damage the natural environment (Frankel, 2009, p. 2). In contrast, trade often becomes an engine of environmental improvement by enabling environmentally-friendly goods and technologies to spread across borders (OECD, 2017).

Agricultural trade has several environmental impacts, such as intensification of food production, deforestation, soil degradation, or displacement of local farmers (Balogh, 2020). Only limited research concludes that the environment could benefit from agricultural trade or has advantageous effects on the natural environment. On the contrary, agricultural production induced by trade expansion is the main engine of global pollution and biodiversity loss (Balogh and Jámbor, 2020). Approximately 24% of the agro-food export is derived from imported inputs such as machinery, fertiliser, services, agriculture and food at the global level (OECD, 2019).

2.4. *Environmental effects of free trade agreements*

Several studies searched for the environmental effects of trade openness. Lucas et al. (1992) point out that trade-distorting policies increase pollution in rapidly growing countries. Dean (2002) found the net beneficial effect of trade liberalization for a given level of income in China.

Free trade agreements can play a significant role in pursuing environmental regulation and adjusting pollution. Specific free trade agreements (FTAs) can induce or alleviate various environmental burdens. Nemati et al. (2019) argue that the ecological impacts of FTAs depend on the different types of treaties. In the case of FTAs being signed only between developed or developing countries, there is no environmental damage, and this might be beneficial for the environment in the long term. By contrast, if developing and developed countries have an agreement it often results in higher GHG emissions. Furthermore, the provisions of free trade agreements regularly support trade facilitation over environmental protection (Heyl et al., 2021).

The member states (Iceland, Liechtenstein and Norway) of the European Free Trade Association (EFTA) recognised the need to surge decarbonisation in all means of transport to meet their commitments under the Paris Agreement. They have ambitious national targets for introducing zero-emission vehicles and low- and zero-emission vessels (EFTA, 2021a). The European Economic Area Agreement comprises acts intended to protect water, the environment and human health from air pollution, the harmful impacts of chemicals, and regulating the waste sector (EFTA, 2021b).

Turning to Asia, the countries of the Association of Southeast Asian Nations (ASEAN) (Malaysia, Indonesia, Philippines, Singapore, and Vietnam) are growing at the expense of their environment and stimulating emission-intensive trade. Agriculture and manufacturing-led exports require electricity and heat, especially in Indonesia, Vietnam, and Malaysia (Solomon and Khan, 2020). Rajão et al. (2020) revealed that traded products between the EU and MERCOSUR encourage deforestation in Brazilian and Argentinian forests. Regarding meat production, MERCOSUR countries trade with the EU, are associated with high resource use, and are a source of multiple environmental concerns (Heyl et al., 2021).

Research by Abler and Pick (1993) concluded that NAFTA was environmentally disadvantageous to Mexico and beneficial for the United States. Yu et al. (2010) argued that free trade between the United States and Mexico increased greenhouse gas emissions in both states. Finally, NAFTA allowed only limited ground for environmental protection and did not comply with international climate mitigation goals (Balogh and Mizik, 2021).

Literature underlines that negotiation and trade rules under the World Trade Organization (WTO) are insufficient to achieve a stark emission reduction. In addition to this, the world largest fossil fuel exporters had not historically been members of the World Trade

[3] Vicious circle of poverty implies that poverty is the cause of poverty. A poor person, in order to repay his existing debt, will borrow some more, thereby adding to his debt. Further, he will also incur interest payment obligations. This will only increase his total amount of debt.

Organization, consequently, they can avoid environmental rules (Meyer, 2017).

However, eliminating trade barriers stimulates trade flows, but this, at the same time, may also increase GHG emissions as well. Globally, the greatest beneficiaries of the trade agreements are generally the highest GHG emitters (such as China, the US, and the EU), while developing countries are in a weaker position in climate–trade disputes (Balogh and Mizik, 2021).

2.5. Regional level studies analysing Non-EU countries

In addition to the European Union, the rest of the world is also an important engine of greenhouse gas emissions. At regional level, 15–32 % of total agricultural land and emissions were associated with change in Brazil and Indonesia due to exports of bovine meat and palm oil exports (Saikku et al., 2012). Moreover, the increasing share of primary commodity export in total agricultural production lifted GHG emissions (Drabo, 2017). Besides, groundwater exhaustion, loss of species, and drier climate were the most important results of trade-related pollution in Africa and South America (Balogh and Jámbor, 2020). Agriculture accounts for 17 % of total GHG emissions in China. To address this issue, agricultural best practices should be adopted to reduce Chinese GHG emissions, such as a proper application of agrochemicals, improvement of ruminant nutrients, and intermittent irrigation of rice fields (Dong et al., 2008). Instead of setting incoherent and incompatible policy goals, technology and institutional innovation would lead to more integrated sustainable development in China (Yu and Wu, 2018). Agricultural production accounts for 18 % of total GHG emissions in India (INCCA, 2010). Sectors such as livestock and rice production are the main sources of GHG emissions in Indian agriculture, therefore, a shift to dietary patterns with consumption of animal foods could significantly increase GHG emissions (Vetter et al., 2017). Sarkodie (2018) revealed that energy consumption, food production, economic growth, permanent crops, agricultural land, and population growth play a key role in environmental degradation in Africa. GHG emissions from the agricultural sector accounted for 10% of total US emissions in 2019, and have increased by 12 % since 1990 (EPA, 2021). In summary, studies exploring agriculture-trade-environment linkage are usually considered agriculture and agricultural trade as significant factors influencing environmental pollution. In contrast, the distinct role of agricultural activities, the effects of agro-food trade along with FTAs and climate agreements inducing environmental concerns in the Non-EU region is understudied yet.

3. Econometric specifications

In this paper, economic growth, agricultural development, and trade are analysed along with the impact of free trade- and climate agreements. The so-called Environmental Kuznets Curve (EKC) is a hypothetical economic relationship between various indicators of environmental degradation and per capita income. According to this relation, per capita emissions are an inverted U-shaped function of per capita income (Stern, 2018). The econometric estimation of the environmental pollution function, comprising the Environmental Kuznets Curve (Kuznets, 1955; Munasinghe, 1999) can be written as follows (Atici, 2009; Sharma, 2011; Balogh and Jámbor, 2017) for panel data:

$$\ln(CO_2\_per\_capita_{it}) = \alpha + \beta_1 \ln(GDP\_per\_capita_{it}) + \beta_2 \ln(GDP\_per\_capita_{it})^2 + \beta_3 \ln(Agr\_VA_{it}) + \beta_4 \ln(Agr\_machinery_{it} + \beta_5 Agr\_exp_{it} + \beta_6 FTAs_{it} + \beta_7 CA_{it} + d_t + h_i + \varepsilon_{it} \quad (1)$$

where.

α is the constant.

β_i symbolize the estimated coefficient of panel regression.

$\beta_1 \ln(GDP\_per\_capita_{it}) + \beta_2 \ln(GDP\_per\_capita_{it})^2$ denotes the EKC hypothesis.

$FTAs_{it}$ denote EFTA, NAFTA, MERCOSUR or ASEAN.

t captures the time expressed in year.

i illustrates a given country.

d_t represents the common deterministic trend.

h_i capture specific effects.

ε_{it} denotes random disturbance.

Table 1 presents the implied dependent and explanatory panel variables and their related data sources.

In the model, air pollution is illustrated by per capita CO_2 emission (expressed in total GHG emission per capita in CO_2 equivalent). The association of economic development and environmental pollution is measured by per capita GDP and per capita GDP^2, representing the Environmental Kuznets Curve. Agriculture-specific variables are also included in the model as agriculture value-added, expressed as a percent of GDP capturing agricultural development. Furthermore, agricultural trade is denoted by agricultural raw material export as percent of total exports. Last but not least, trade policy variables capture the effects of free trade (WTO membership, EFTA, NAFTA, MERCOSUR, ASEAN) on climate change, while climate policy variables such as climate agreements (covering Kyoto Protocol and Paris Agreement) are also tested. Finally, dummy variables are used for measuring the country level

Table 1
Variables applied.

Variable	Description	Source
$\ln(CO2\_per\_capita_{it})$	carbon dioxide emissions in metric tons per capita for country i and at time t in logarithm	World Bank (2021) World Development Indicator (WDI)
$\ln(GDP\_per\_capita_{it})$	Gross Domestic Product (GDP) per capita in current USD for country i and at time t in logarithm	World Bank (2021) World Development Indicator (WDI)
$\ln(GDP\_per\_capita_{it})^2$	squared term of per capita Gross Domestic Product (GDP) in current USD for country i and at time t in logarithm	own composition based on World Bank (2021) World Development Indicator (WDI) GDPPC data
$\ln(Agr\_machinery_{it})$	Agricultural machinery, tractors per 100 square km of arable land in logarithm	World Bank (2021) World Development Indicator (WDI)
$\ln(Agr\_VA_{it})$	Agriculture, forestry, and fishing, value added per worker in constant 2010 USD for country i and at time t in logarithm	World Bank (2021) World Development Indicator (WDI)
Agr_exp_{it}	Agricultural raw materials exports in percent of merchandise exports for country i and at time t	World Bank (2021) World Development Indicator (WDI)
WTO	WTO membership, 1 if a country i is a member of the WTO at time t, 0 otherwise	own composition based on WTO (2021) website
CA_{it}	if the given country signed either the Kyoto Protocol or Paris agreement or both at time t, 0 otherwise	own composition based on UN Treaty Collection (2021)
$EFTA_{it}$	1 if country i is a member of the EFTA at time t, 0 otherwise	own composition based on online sources
$NAFTA_{it}$	1 if country i is a member of the NAFTA at time t, 0 otherwise	own composition based on online sources
$MERCOSUR_{it}$	1 if country i is a member of the MERCOSUR at time t, 0 otherwise	own composition based on online sources
$ASEAN_{it}$	1 if country i is a member of the ASEAN at time t, 0 otherwise	own composition based on online sources
Specific country variables (dummy)	1 if country i belongs to the USA / China / India / Brazil / Russia, 0 otherwise	own composition

Source: own composition.

impacts of the biggest emitters for the Non-EU countries as the USA, China, India, Brazil, and Russia. This article considers six hypotheses that address the polluting effect of agriculture and trade.

Hypothesis 1. *A higher level of economic development, after reaching a turning point, curbs air pollution in Non-EU countries (representing the hypothesis on Environmental Kuznets Curve).*

This hypothesis is supported earlier by extended literature (Stern, 2004, Munasinghe, 1999; Balibey, 2015; Li et al., 2015, Stern, 2018; Uddin, 2020).

Recent studies have focused on polluting effect of agricultural production and development (Baccini et al., 2012; Henders et al., 2015; Maraseni et al., 2018; Lamb et al., 2021). Hypothesis 2 captures this impact on emissions.

Hypothesis 2. *Agricultural development through extended production and resource use boosts carbon dioxide emissions that cause higher environmental pressure and pollution level in the Non-EU countries.*

Himics et al. (2018) proved that due to emission leakage caused by EU policies, production often increases in less emission-efficient regions in the world especially in Non-EU countries. Hypothesis 3 captures this relationship.

Hypothesis 3. *Agricultural and trade policy of world biggest producers stimulates GHG emissions in third countries through emissions embodied in trade.*

Although considerable research has been devoted to analysing trade liberalization and free trade agreements, only a few articles (Solomon and Khan, 2020; Heyl et al., 2021; Balogh and Mizik, 2021) investigated the environmental impact of such agreements. In this context, the fourth hypothesis examines the impact of free trade agreements (WTO membership, several FTAs) on CO_2 emission.

Hypothesis 4. *Free trade agreements between Non-EU countries (EFTA, NAFTA, MERCOSUR, ASEAN) by their climate provisions can contribute to the efforts of CO_2 emission reduction.*

The Kyoto Protocol introduced emission reduction targets for developed countries, however, the success of the agreement was limited due to the lack of effort made by developed and developing countries. Under the Paris Agreement many ratifying states are committed to limiting global warming, keeping temperature rise at 1.5 degrees Celsius. These agreements also have a significant impact on national and global emissions.

Hypothesis 5. *Ratification of international climate agreements (Kyoto Protocol, Paris Agreements) encourages countries‘ commitment leading to lower CO_2 emissions.*

The international climate agreements aim to limit global level GHG emissions. In contrast to the EU, which have already made significant efforts to cut emissions, the majority of the biggest polluters (e.g. China, India, Russia, and Australia) still do not have ambitious and feasible emission targets enough. The sixth hypothesis captures these effects.

Hypothesis 6. *The biggest GHG emitters as the USA, China, India, Japan, and Brazil are the engines of pollution, contributed to the GHG emission growth significantly during the period analysed at global level.*

4. Data and methodology

This paper uses a panel data set to investigate whether economic growth, agricultural development and trade influence GHG emissions. All applied environmental and agricultural indicators are derived from the World Bank (2021) World Development Indicator (WDI) database. The dummy variables were obtained from the UN Treaty Collection (2021) data. A strongly balanced panel data set is created that includes 152 Non-EU countries for the period of 2000–2018 (19 years). Detailed descriptive statistics are presented in Appendix A.

Since the variables contain unit root and are assumed to be cointegrated, following Appiah et al. (2018), Fully Modified Ordinary Least Squares (FMOLS), and Dynamic Ordinary Least Squares (DOLS) are employed as estimation methods.

FMOLS regression (Phillips and Hansen, 1990) provides optimal estimates of cointegrating regressions. This method modifies least squares to account for serial correlation and the endogeneity in the regressors as a result of the presence of a cointegrating relationship of variables (Rukhsana and Shahbaz, 2009). Additionally, DOLS estimation is an alternative parametric approach in which lags and leads are introduced to cope with the problem irrespectively of the order of integration and the existence or absence of cointegration. Similarly to this study, Appiah et al. (2018) employed FMOLS and DOLS estimation to analyse the relationship between agriculture production and carbon dioxide emissions in emerging economies.

4.1. Panel data tests

Before estimating the econometric models demonstrating the impact of the agricultural sector on environmental pollution, panel variables are pretested by several statistical methods (Wooldridge, 2002; Drukker, 2003; Pesaran, 2004, 2007; Maddala and Wu, 1999; Kao, 1999; Pedroni, 1999, 2004; Westerlund, 2005; Dumitrescu and Hurlin, 2012). Wooldridge (2002) technique is used for exploring the existence of the first-order autocorrelation (serial correlation) in the panel. In the case of serial correlation, linear dynamic panel-data models include p lags of the dependent variable as covariates and contain unobserved panel-level effects (fixed or random effects). A significant test statistic ($p = 0.000$) of the Wooldridge (2002) autocorrelation test indicates the presence of serial correlation in the data. In addition to Wooldridge (2002) test, Pesaran (2004) test is applied for examining cross-section (CD) independence. The CD test rejects the null hypothesis of cross-sectional independence (except ln_Agr_machinery), suggesting that the series is cross-sectionally dependent (Table 2).

In panel data, unit root tests are applied to calculate the stationarity of the variables. Unit root tests can be divided into first- or second-generation type tests. The advanced second-generation unit root tests (Maddala and Wu, 1999; Pesaran, 2007) also account for the existence of cross-sectional dependence (Pesaran, 2004). As variables are cross-sectionally dependent, Pesaran (2007) CIPS panel unit root tests are more consistent. The result of CIPS panel unit root tests (including lags 0–1) reveals that CO_2 per capita and squared GDP per capita have unit roots, suggesting that these variables are nonstationary (Table 3).

To deal with non-stationarity, panel cointegration tests were performed as the next step. Various cointegration tests are valid only if the variables have the same order of integration. When all series are integrated into the same order, Pedroni (1999, 2004), Kao (1999) and Westerlund (2005) methods are used to test the panel cointegration relationship. Most tests confirmed that a cointegration relationship exists between panels (Table 4).

In the case of the cointegrated relationship between variables, the direction of causality between the variables can be examined by the Granger causality test (Engle and Granger, 1987; Oxley and Greasley, 1998). The panel cointegration test allows testing for Granger non-causality from independent to dependent variable in heterogeneous panels using the procedure proposed by Dumitrescu and Hurlin (2012). A variable is said to Granger-cause another variable if it is helpful for forecasting the other variable. Fail to Granger cause if it is not useful for forecasting the other variable. In this dataset, the null hypothesis of Granger non-causality is rejected (Table 5), which supports that applied independent variables (GDP per capita, GDP per capita squared) to help forecast the dependent variable (CO_2 per capita emission).

Based on the test results (existence of serial correlation and cross-sectional dependency, non-stationary cointegrated panel), FMOLS and DOLS estimation methods are selected.

Table 2
Pesaran (2004) CD test for cross-section independence.

Variable	CD-test	p value	Null hypothesis	Decision
ln(CO2_per_capita)	37.87	0.000	cross-sectional independence	reject
ln(GDP_per_capita)	476.80	0.000	cross-sectional independence	reject
ln(GDP_per_capita)^2	474.77	0.000	cross-sectional independence	reject
ln(AgrVA)	168.978	0.000	cross-sectional independence	reject
ln(Agr_machinery)	0.642	0.521	cross-sectional independence	accept
Agr_exp	36.96	0.000	cross-sectional independence	reject

Note: cross-sectional independence CD ~ N(0,1).
Source: own composition.

Table 3
Pesaran (2007) CIPS Panel Unit Root test.

Specification without trend				
Variable	lags	Zt-bar	p-value	Decision
ln(CO2_per_capita)	0	-1.505	0.066	accept
ln(CO2_per_capita)	1	-1.594	0.055	accept
Specification with trend				
ln(CO2_per_capita)	0	-0.670	0.252	accept
ln(CO2_per_capita)	1	-0.859	0.195	accept
Specification without trend				
Variable	lags	Zt-bar	p-value	
ln(GDP_per_capita)	0	-7.556	0.000	reject
ln(GDP_per_capita)	1	-7.779	0.000	reject
Specification with trend				
ln(GDP_per_capita)	0	-2.471	0.000	reject
ln(GDP_per_capita)	1	-5.155	0.007	reject
Specification without trend				
Variable	lags	Zt-bar	p-value	
ln(GDP_per_capita)^2	0	-5.678	0.000	reject
ln(GDP_per_capita)^2	1	-6.631	0.000	reject
Specification with trend				
ln(GDP_per_capita)^2	0	-0.724	0.235	accept
ln(GDP_per_capita)^2	1	-3.854	0.000	accept

source: own composition.

Table 4 Panel cointegration tests
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Kao (1999) test for cointegration	Statistic	p-value	results
Modified Dickey-Fuller t	-5.044	0.000	cointegrated in all panels
Dickey-Fuller t	-4.106	0.000	cointegrated in all panels
Augmented Dickey-Fuller t	1.872	0.031	cointegrated in all panels
Unadjusted modified Dickey-Fuller t	-6.568	0.000	cointegrated in all panels
Unadjusted Dickey-Fuller t	-4.912	0.000	cointegrated in all panels
Pedroni (1999, 2004) test for cointegration	Statistic	p-value	
Modified Phillips-Perron t	5.951	0.000	cointegrated in all panels
Phillips-Perron t	-2.992	0.001	cointegrated in all panels
Augmented Dickey-Fuller t	-1.069	0.143	no cointegration
Ho: No cointegration			
Ha: All panels are cointegrated			
Westerlund (2005) test for cointegration	Statistic	p-value	
Variance ratio	-0.212	0.416	no cointegration
Ho: No cointegration			
Ha: Some panels are cointegrated			

Source: own composition.

Table 5
Results for Granger non-causality test (Dumitrescu and Hurlin, 2012).

Granger non-causality test results	AIC Optimal lags 7		BIC Optimal lags 1	
Test null hypothesis	p-value	p-value	p-value	p-value
H0: ln(GDP_per_capita) does not Granger-cause ln(CO_2_per_capita)	0.000	0.000	0.000	0.000
H0: ln(GDP_per_capita)^2 does not Granger-cause ln(CO_2_per_capita)	0.000	0.000	0.000	0.000
H0: ln(CO_2_per_capita) does not Granger-cause ln(GDP_per_capita)	0.000	0.000	0.000	0.000
H0: ln(CO_2_per_capita) does not Granger-cause ln(GDP_per_capita)^2	0.000	0.000	0.000	0.000

Note: AIC - Akaike information criterion, BIC - Bayesian information criterion.
Source: own composition.

Table 6
FMOLS and DOLS estimation results, standard models, 2000–2018.

	(1)	(2)
	FMOLS	DOLS
Variables	ln(CO2_per_capita)	ln(CO2_per_capita)
ln(GDP_per_capita)	1.977***	1.780***
	(0.365)	(0.488)
ln(GDP_per_capita)^2	-0.083***	-0.073***
	(0.021)	(0.028)
ln(AgrVA)	0.077	0.082
	(0.068)	(0.087)
ln(Agr_machinery)	0.121***	0.123***
	(0.033)	(0.043)
Agr_exp	-0.00321	0.00235
	(0.011)	(0.014)
WTO	-0.598***	-0.713***
	(0.118)	(0.152)
CA	-0.238**	-0.388**
	(0.098)	(0.154)
Constant	-10.13***	-9.126***
	(1.439)	(1.935)
Observations	438	436
R-squared	0.185	0.731

Note: FMOLS - Fully Modified Ordinary Least Squares, DOLS - Dynamic Ordinary Least Squares
Robust standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

5. Results

Panel regression tables (Tables 6–8) demonstrate the estimation for Eq. (1) with FMOLS and DOLS methods. Firstly, the estimations show that the EKC relation exists in the Non-EU countries. More specifically, the results confirmed the validity of the U-shaped EKC curve (the positive sign of GDP per capita and a negative coefficient for per capita GDP^2 on GHG emissions) for Non-EU countries, validating that a higher level of economic development contributes to reducing carbon dioxide emission. Secondly, coefficients of agricultural development

Table 7
FMOLS and DOLS estimation results for FTAs, 2000–2018.

	(1)	(2)
	FMOLS	DOLS
VARIABLES	ln(CO_2_per_capita)	ln(CO_2_per_capita)
ln(GDP_per_capita)	1.537***	0.884**
	(0.271)	(0.398)
ln(GDP_per_capita)^2	-0.059***	-0.020
	(0.016)	(0.024)
ln(AgrVA)	0.160***	0.148***
	(0.041)	(0.054)
ln(Agr_machinery)	0.117***	0.098***
	(0.020)	(0.027)
Agr_exp	-0.017**	-0.026***
	(0.007)	(0.009)
NAFTA	0.075	-0.147
	(0.151)	(0.191)
EFTA	-1.010***	-1.212***
	(0.183)	(0.242)
MERCOSUR	-0.957***	-0.730***
	(0.123)	(0.157)
ASEAN	-0.288**	-0.649***
	(0.145)	(0.212)
Constant	-9.246***	-6.371***
	(1.053)	(1.571)
Observations	438	436
R-squared	0.264	0.746

Robust standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 8
FMOLS and DOLS estimation results for biggest emitters, 2000–2018.

	(1)	(2)
	FMOLS	DOLS
VARIABLES	ln(CO_2_per_capita)	ln(CO_2_per_capita)
ln(GDP_per_capita)	1.960***	1.785***
	(0.251)	(0.436)
ln(GDP_per_capita)^2	-0.087***	-0.081***
	(0.015)	(0.025)
ln(AgrVA)	0.067	0.104
	(0.044)	(0.072)
ln(Agr_machinery)	0.134***	0.108***
	(0.023)	(0.039)
Agr_exp	-0.020***	-0.028**
	(0.007)	(0.011)
USA	0.745***	0.653*
	(0.245)	(0.379)
China	0.860	-0.734
	(0.636)	(1.811)
Japan	-0.275	0.276
	(0.276)	(0.439)
India	0.263	0.543
	(0.327)	(0.581)
Brazil	-0.592**	-0.618
	(0.244)	(0.385)
Russia	1.251***	1.301***
	(0.207)	(0.320)
Constant	-10.25***	-9.460***
	(0.996)	(1.736)
Observations	438	436
R-squared	0.398	0.733

Robust standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

(Agriculture, forestry, and fishing, value-added per worker) and machinery use (Agricultural machinery, tractors per 100 square km of arable land) through expanding production volume pointed out the increasing CO_2 emission in third countries, however, ln(AgrVA) was insignificant in every model (Table 6). Estimation shows that export of international agricultural raw materials shrinks GHGs in the rest of the world, highlighting the possible concerns of trade-related emissions and emission embodied in trade (exporting emissions from one country to another country). Table 6 also shed light that trade under the WTO agreement provides fewer environmental burdens in the rest of the world. Countries' ratification of the climate agreements (Kyoto Protocol and Paris Agreement) facilitated cutting back CO_2 emissions in Non-EU countries.

Most free trade agreements enhanced emission reduction in all models estimated for the period studied (Table 7). Specific Free Trade Agreements analysed as EFTA, ASEAN, and MERCOSUR appear to support CO_2 emission reduction, while the impact of NAFTA is controversial, slightly encouraged emission growth (Table 7) in line with the literature (Abler and Pick, 1993; Balogh and Mizik, 2021). Furthermore, the highest shrinking effects are attributed to EFTA, followed by MERCOSUR and ASEAN.

The result indicates that the biggest polluters as the USA, China, India, Japan, and Russia did not slow down their GHGs significantly and carbon dioxide emissions between 2000 and 2018 (Table 8). The highest coefficients were attributed to Russia, China and the USA, followed by India and Japan. However, estimation was significant only in the case of Russia and the USA. The value of panel R-squared varied from 0.147 to 0.731 in the models. Despite the international efforts, agricultural development has stimulated climate change via GHG emissions confirmed by the estimates. Within agriculture, the livestock sector and manure management still have a high carbon emission, highlighting emission cuts needed in global agriculture. These findings call attention to the limited progress and implementation of global climate policies in the developed and developing world outside of the EU between 2000 and 2018.

6. Conclusion and discussion

Overpassing the European Union, the contributions of the third countries to climate change - referred to as Non-EU nations - are also significant. However, many states submitted new emission targets at the end of 2021, but the pledges of many developed or developing countries were not ambitious enough.

The paper analysed the economic growth, agriculture and trade-related explanatory factors of CO_2 emission, focusing on the contribution of the rest of the world (Non-EU countries), exploring the country effects of the highest polluters in the past decades. A strongly balanced panel data set is constructed, covering 152 Non-EU countries from 2000 to 2018. Before estimating the econometric models, the variables were tested for serial correlation, cointegration, and Granger causality. Since the variables contained unit roots and were cointegrated, FMOLS and DOLS methods were employed along with the literature (Appiah et al., 2018). The results proved the validity of the U-shaped EKC curve relationship for the Non-EU countries, suggesting that higher economic development, after reaching a given turning point, contributes to reducing carbon dioxide emission, showing greener economic pattern. Estimation of agricultural development revealed increasing CO_2 emission in third countries; however, some of these variables were insignificant in the model. Regression analysis showed that agricultural export has a sinking impact on GHGs in the rest of the world, underlining the potential hidden effect of trade-embodied emission. As concerns agreements on free trade, EFTA, ASEAN, and MERCOSUR assisted diminishing CO_2 emission while NAFTA[4] encouraged emission growth and environmental concerns (Abler and Pick, 1993; Balogh and Mizik, 2021). The world's largest emitters (the USA, China, India, Japan, and Russia) were unable to slow down their agriculture-related greenhouse gas emissions during the period analysed. The highest estimated coefficients were devoted to Russia, China and the USA, shadowed by India

[4] It should be noted, that this agreement was modified to include Canada (the United States-Mexico-Canada Agreement, USMCA), and replaced NAFTA from July 2020.

and Japan. Similar results were stressed by CAT (2022a).

As policy recommendations, countries such as the USA, China and Russia have the highest responsibility in controlling or abating climate change in Non-EU countries. Agricultural trade may induce significant environmental degradation in Non-EU import markets, as well as its export destination markets, by increasing agricultural production intensity, land use change, and the boom of export-oriented agricultural products, extending agricultural land area and reducing local biodiversity. The findings reflect the limited progress and implementation of global climate policies and agricultural policy-related emissions in Non-EU countries, especially in the highest polluters such as China, the US, India, Brazil, and Australia. This is also confirmed by Climate Action Tracker, namely, none of the countries ranked as 1.5 Celsius compatible and only 9 countries satisfy the 'almost sufficient' category of Paris Agreement (CAT, 2022b).

The contribution of the research was to explore the role of economic growth (Environmental Kuznets Curve), agricultural development (agricultural value added, agricultural machinery), trade (agricultural trade) and free trade agreements played in GHG emissions to meet the pledges of the Paris Agreement focusing on Non-EU countries.

Both improved agricultural management and changes in dietary consumption would provide considerable GHG in China (Yue et al., 2017) and India. Supply (agricultural production and trade) and demand (consumption choices) can highly influence total GHG emissions, therefore, the application of low carbon plant varieties would be required in Asian and American countries (Vetter et al., 2017). Climate agreements must be more active in managing and coordinating the global trade system (Dent, 2021). Without the countries which have only resubmitted the same or less ambitious national emission targets or those who are not a member of the WTO, the race to zero-emission and control global temperature change would have not been achieved. These countries should consider WTO membership or free trade agreement as a tool to limit trade-related emissions and demolish trade barriers at the same time.

This study has some limitations. Firstly, the European Union Member States were not included in the analysis. Secondly, not all explanatory variables in the panel were strongly balanced in the sample (Appendix A). Some observations were lost during data transformation (balancing panel data). Future research would assess the impact of third countries' agricultural policies and agricultural subsidies on carbon emissions. Another direction for further research is to analyse agricultural land-use change-related emissions by the most important agricultural sectors.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Jeremiás Máté Balogh reports financial support was provided by Corvinus Institute for Advanced Studies (CIAS), Corvinus University of Budapest, Hungary.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.envsci.2022.08.012.

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